Universidade de Lisboa
Faculdade de Ciências
Departamento de Biologia Animal

# Fisheries landings variability for different fleet components along the Portuguese coast

**Sandra Isabel Amoroso Ferreira**

Dissertação

Mestrado em Ecologia Marinha

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Tese Orientada por:
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**2013**

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# Resumo

O sector das pescas tem sido desde sempre uma importante fonte de alimento para a população a nível mundial. Providencia emprego e meios de subsistência em todo o Mundo e os seus produtos são dos mais comercializados globalmente, sendo portanto uma indústria com grande relevância sócio-económica e bastante competitiva. Ao longo dos anos têm sido tomadas as mais variadas medidas de gestão para regular as pescas a nível mundial, as quais se têm mostrado ineficientes. A maioria dos estudos efectuados na área das pescas baseia-se em poucas espécies ou em séries temporais curtas, o que torna difícil atingir uma compreensão pormenorizada sobre como o ambiente e esta indústria interagem, reflectindo-se em consequências na gestão das pescas. Outro problema relacionado com estes estudos é o facto de nem sempre se conseguir obter informação rigorosa acerca dos desembarques. Segundo os relatórios da *Food and Agriculture Organization* (FAO) sabe-se que actualmente cerca de 57% dos *stocks* de peixe estão totalmente explorados e 30% estão sobrexplorados, e apesar de actualmente os desembarques estarem a sofrer quedas significativas, continuam a ser três vezes superiores aos registados na década de 1950. Esta situação torna-se mais preocupante numa população mundial em crescimento e que demonstra cada vez mais a procura por produtos da pesca para incluir nos seus hábitos alimentares. Sendo uma indústria com um elevado potencial para o combate contra a pobreza e considerando a actual crise económica em que se encontra a sociedade mundial, é preocupante a contínua subida nos preços dos produtos pesqueiros, em muito devido à escassez dos recursos e ao maior esforço de pesca necessário por parte dos pescadores para explorar os mesmos de forma lucrativa. Para além disto, em muitas regiões as condições de vida dos pescadores são precárias e este trabalho proporciona-lhes cada vez menos sustento, o que tem vindo a tornar o sector piscatório cada vez menos atractivo. Esta dificuldade advém também das medidas de gestão aplicadas, que em muitos casos atingem economicamente as comunidades dependentes da pesca, visto que muitas vezes não são as grandes indústrias de pesca que são gravemente prejudicadas, mas sim a pesca artesanal de pequena escala da qual muitos pescadores dependem para sustentar o seu dia-a-dia. Portugal tem sido desde sempre um país de tradições e culturas estreitamente relacionadas com a pesca e com o mar, sendo actualmente o maior consumidor de peixe *per capita* ao nível da União Europeia e o terceiro maior consumidor a nível mundial. Para além disto, é um dos países com maior Zona Económica Exclusiva e possui uma elevada quantidade de espécies comerciais importantes, factores que juntos geram uma grande potencialidade global no que diz respeito à indústria das pescas. No entanto, encontra-se igualmente em estado precário no que diz respeito ao sector das pescas, com o declínio da frota, do efectivo de pescadores e dos desembarques. Para a realização do presente trabalho foram analisados dados oficiais de desembarques das três principais componentes da frota nacional – arrasto, cerco e polivalente – ao longo da costa continental portuguesa, assim como os preços de venda em lota para as espécies desembarcadas. Foram analisados dados de desembarques de 3809 embarcações, tendo sido excluídas da análise aquelas que tenham efectuado desembarques ao longo de um período inferior a 10 anos e que efectuaram desembarques ocasionais ou correspondentes a mais do que um segmento de frota. O estudo de tendências de desembarque foi efectuado através da análise dos desembarques por unidade de esforço (DPUE) efectuados ao longo da série temporal considerada (1992-2012). Foram identificadas as espécies dominantes em termos quantitativos (kg) e em termos de valor (€). Foi também analisada a variabilidade associada aos desembarques, tanto entre as artes de pesca (inter-segmento de frota) como entre sectores da costa para cada arte de pesca (intra-segmento de frota), sendo que para a última foi realizada *a priori* uma análise *bootstrap*, com o objectivo de proporcionar confiança à escolha da dimensão amostral. Os resultados obtidos demonstraram, no geral, uma tendência crescente tanto nos desembarques por unidade de esforço como no preço de venda em lota por unidade de peso, apesar de ser

perceptível alguma instabilidade. O cerco é a arte de pesca que possui claramente valores mais elevados de desembarques por unidade de esforço, cujo valor máximo registado foi de 1 062.09 kg.dia$^{-1}$.embarcação$^{-1}$. No que diz respeito às componentes de arrasto e ao polivalente, os valores máximos verificados são 22.26 kg.dia$^{-1}$.embarcação$^{-1}$ e 0.16 kg.dia$^{-1}$.embarcação$^{-1}$, respectivamente. Pelo contrário, o polivalente foi a componente da frota que apresentou, considerando o conjunto dos sectores, valores mais elevados de preço por kg para o total dos desembarques, com o valor médio máximo de 3.73 €.kg$^{-1}$, apesar de individualmente ser no sector Sul do arrasto que se verificaram os valores médios mais elevados, atingindo cerca de 6.20 €.kg$^{-1}$, devido à captura de lagostim e camarões. Os valores mais baixos em relação ao preço médio correspondem ao cerco com o valor máximo de apenas 1.01 €.kg$^{-1}$. Foi também verificado que as espécies dominantes nos desembarques globais são o carapau, a sardinha e o polvo, com desembarques médios anuais que rondam respectivamente os 10 milhões kg.ano$^{-1}$, 22 milhões kg.ano$^{-1}$ e 3 milhões kg.ano$^{-1}$, o que os distingue claramente das restantes. As espécies cujo preço por kg é mais elevado são o lagostim, os camarões e os linguados, cujos valores médios respectivos de venda são 6.22 €.kg$^{-1}$, 11.86 €.kg$^{-1}$ e 10.55 €.kg$^{-1}$, sendo que o polivalente é a arte de pesca cujos produtos possuem, no geral, maior valor económico por kg. O carapau, a sardinha, a faneca, o peixe-espada e a cavala foram as espécies que demonstraram mais potencial de confiança e estabilidade para os pescadores devido a serem as espécies que demonstraram mais estabilidade e consistência nas tendências de desembarques e de preço. Quanto à variabilidade, o cerco foi a arte de pesca que demonstrou uma maior expressão deste factor devido à grande amplitude dos valores médios dos desembarques desde 2 772.42 kg.embarcação$^{-1}$ a 163 210.09 kg.embarcação$^{-1}$. O polivalente foi a componente que apresentou menor variabilidade nos referidos valores, variando desde 43.94 kg.embarcação$^{-1}$ a 1 822.90 kg.embarcação$^{-1}$, demonstrando uma variabilidade bastante reduzida. No que diz respeito aos sectores da costa, no geral, foi o

Norte que apresentou maior variabilidade nos desembarques no que corresponde às três componentes de frota, com uma variação de valores desde 10.59 kg.embarcação$^{-1}$ até 163 210.09 kg.embarcação$^{-1}$, correspondentes respectivamente ao polivalente e ao cerco. Para atingir a sustentabilidade do sector pesqueiro é necessário ter em conta os factores descritos. Não são só as pescas que afectam o estado dos recursos e os valores dos desembarques. O meio marinho é bastante dinâmico e tem uma grande variabilidade associada. Como tal, vários factores têm influência sobre os seus padrões e flutuações, tais como as alterações climáticas, o recrutamento, a sazonalidade, outras pressões antropogénicas e catástrofes ambientais, entre outros. Estes factores vão influenciar a variabilidade do ecossistema e das pescas, sendo portanto necessário compreender até que ponto afectam a exploração dos recursos marinhos e como inserir a variabilidade e as respectivas causas e consequências no planeamento da gestão ambiental e da indústria pesqueira. A gestão das pescas precisa de uma nova visão a nível global baseada no ecossistema e nas interacções entre as suas comunidade e o meio ambiente, na qualidade de vida da população, assim como na economia dependente das pescas. É necessária também a busca por espécies alternativas para consumo, sensibilizando a população à pratica de um consumo sustentável e chamando a atenção da mesma para a importância que a preservação dos recursos tem não só para o ambiente mas também para a nossa sociedade e para o respectivo estilo de vida que esta pratica. Um factor muito importante para melhor conseguirmos avaliar o estado de abundância e de exploração dos *stocks*, assim como a evolução das capturas seria a obtenção dos valores efectivos das capturas e não apenas dos desembarques, pois estes últimos não incluem as rejeições nem as vendas anteriores à lota. A participação pública seria essencial à conjugação da sustentabilidade sócio-económica com a sustentabilidade ambiental, a qual não é possível de atingir sem a existência da primeira. Para além disso, o conhecimento e a experiência dos pescadores são extremamente valiosos e estes devem, portanto, ter mais oportunidade para exprimir a sua opinião e participar nas decisões relacionadas com a gestão das pescas. Com metas importantes a atingirem os seus prazos finais, é essencial atingir a sustentabilidade dos recursos, assim como da indústria das pescas. É para isso importante a existência de uma harmonia entre as medidas de gestão a nível mundial, o que requer uma maior capacidade de comunicação e colaboração entre os decisores dos vários países e comunidades, visto que no que diz respeito aos recursos não existem fronteiras passíveis de se impor.

**Keywords:** Pescas; desembarques; preço de lota; variabilidade; segmento de frota; Portugal

# Summary

Fisheries are an important socio-economic activity for the worldwide population. This industry provides food, jobs and livelihoods, and its products are among the most traded goods globally. Currently, the majority of the fish stocks are overexploited, but the fishing effort continues to intensify. In addition, the fisheries sector is becoming professionally less attractive. More multi-specific studies with long-time series are needed to evaluate the evolution of fishing industry and the state of stocks, taking into account the interaction with the environment. Variability is an inherent characteristic of the marine ecosystem and consequently of the fishing industry. This factor is of great importance to understand the dynamics of resources and so also to the fishermen who depend on them and on the prediction of their patterns. In this study, the official data of landings in mainland Portugal in the period from 1992 to 2012, as well as the market price, were analyzed. The vessels with only one of the considered fleet component and with at least 10 years of landings were chosen. Trends of landings and market price were obtained, as well as the dominant species with regard to landed weight and economic value. The variability of landings for both fishing gear and the coast sector it was also studied. Landings and market price have shown increasing trends. Horse mackerel, European pilchard and octopus were the most exploited species, with average landing values of about 10 million kg.year$^{-1}$, 22 million kg.year$^{-1}$ and 3 million kg.year$^{-1}$, respectively. Norway lobster, shrimps and soles were the species with highest average value of price per kg, as their values were of 16.22 €.kg$^{-1}$, 11.86 €.kg$^{-1}$ and 10.55 €.kg$^{-1}$. Purse seine fishing was the dominant fleet component in what concerns to landing values, presented the maximum value of 1 062.09 kg.days$^{-1}$.vessel$^{-1}$, and multigear fishing was the one with lower values with the maximum value of 0.16 kg.days$^{-1}$.vessel$^{-1}$. Purse seine fishing was also the component that showed more variability, with values ranging from 2 772.42 kg.vessel$^{-1}$ to 163 210.09 kg.vessel$^{-1}$, as well as the North sector, varying from 10.59 kg.vessel$^{-1}$ to 163 210.09 kg.vessel$^{-1}$. Multigear fishing, as well as the

Southwest sector, showed the lower variability, with the respective values ranging from 43.94 $kg.vessel^{-1}$ to 1 822.90 $kg.vessel^{-1}$ and from 16.71 $kg.vessel^{-1}$ to 117 985.00 $kg.vessel^{-1}$. More detailed studies will be necessary to evaluate specifically the variability as well as its causes and consequences for the ecosystem and for the management of the fisheries sector. Despite all the measures that have been taken, it is currently global consensus that the fishing industry is experiencing a serious economic and environmental crisis. We don´t know how long marine resources could sustain the growing population and its increasing demand for fish products. In order to find more efficient solutions, fisheries management should take into account the variability factor for the implemented measures, as well as the ecosystem interactions.

**Keywords:** fisheries; landings; market price; variability; fleet component; Portugal

# *Chapter 1*

# General Introduction

Fisheries has always been an important economic and cultural activity for the human being, making it essential to understand its patterns and evolution enabling an assessment that provides stability and reduces its impacts, in order for it to become more sustainable. The products of the fisheries sector are among the most traded goods worldwide, and currently they represent over 10% of exports related to agriculture and 1% of the total world market (Allison & Ellis, 2001; Worm et al., 2006; Allison et al., 2009; Coulthard et al., 2011; FAO, 2012).

However, many countries fail when it comes to providing information on global inventories, such as FAO database, occurring gaps or lack of information (Anticamara et al., 2011). Several participants report most of its fishing statistics referring only to large groups aggregated like “miscellaneous marine fishes” rather than referring specifically species landed (Watson & Pauly, 2001; Pauly et al., 2005). These lead to a growing need for collecting precise information and for more detailed studies, at various scales, on the variability of fishing activity and its influence on resources and population.

A FAO report (2012) presents the total number of fishing vessels in 2010 as 4.36 million worldwide, mentioning that marine fisheries supply about 80 million tons of fish globally, a quite different amount of the approximately 17 million tons in the 1950´s. It is also known that the fishing effort was constant between the 1950´s and 1970´s, after which it kept growing until the present, and by 2010 the increment reaches 54%, with Europe leading the fishing effort worldwide, followed by Asia (Anticamara et al., 2011). In fact, fishing landings have suffered a decline of 0.36 million tons per year since 1988 (Baeta, 2009). Despite this, actual landings are nowadays three times higher than those recorded in the 1950´s (Watson & Pauly, 2013).

The proportion of stocks not fully exploited has been decreasing gradually since 1974, in contrast to the overexploited that has increased. Currently about 57% of the global fish stocks are fully exploited, including most stocks corresponding to the top ten species that represent about 30% of the world catch. Of the remainder, 29.9% are overexploited and 17.2% are moderately exploited and under low fishing pressure (FAO, 2012). This becomes worrisome, especially when the growing world population increasingly demonstrates the desire for a diet rich in fish products (Baeta & Cabral, 2005; Keyl & Wolff, 2008; Swartz et al., 2010; FAO, 2012). While in the 1980´s about 60% of fish was produced for human consumption, currently this percentage is over 86%, which is equivalent in 2010 to 128.3 million tons (FAO, 2012).

In the last 45 years, global landings have changed from large piscivorous fishes towards smaller invertebrates and planktivorous fishes, which show significant changes in the structure of marine food webs (Pauly et al., 1998). Currently it is observed a global decline of 0.05-0.10 per decade in the trophic level of landings (Pauly et al., 2002). This implies at a cultural level that the population adapts to the insertion of new types of fish in their diet. In addition the prices of the species that become rarer inflate due to these changes. As fisheries collapse worldwide, mainly in coastal areas, ships improve technologies to locate and capture the remaining scarce resources. This also allows them to explore new fishing areas.

All these factors lead to questions like how long marine resources and the ecosystem will be able to ensure the food requirements of the population, how far is it possible for them to recover and what measures do we need to adopt in order to maintain production and fishing while promoting the recovery of stocks and sustainable fisheries. Among the impacts of fishing on the ecosystem are the high mortality rates and declines in biomass of the target species caused by overfishing, effects of size-selective fishing, reduction of biological and genetic diversity, global decline of big predators, destruction of seabed, destruction of benthic communities and bycatch (Bostford et al., 1997; Pauly et al., 2002; Myers & Worm, 2003; Hutching & Reynolds, 2004; Baeta & Cabral, 2005). Other impacts are due to discharges of organic waste that will pollute the ecosystem, and the loss of fishing gear resulting in ghost fishing.

Several long term measures of management and mitigation of the fishery impacts have been implemented by relevant organizations. In recent years an evolution regarding the scale of action has been noticed, with an effort to apply ecosystem based measures. It is understood today that to protect the species, we have to protect their environment and its resources (Garcia et al., 2003; Fréon et al., 2005). The common assumption that the decline in marine resources is due to direct exploitation is problematic since it is derived from several factors. Pollution, illegal fishing, habitat degradation and climate change, contribute to a large part of the degradation noticed on marine environment and the scarcity of its resources. Also natural phenomena can be misleading in relation to the analysis of fish stocks (Alheit et al., 2005). Marine ecosystem is not only affected by fisheries impacts. It is an extremely dynamic system, as such, influenced by many factors that will lead to a large variation (Halley and Stergiou, 2005; Drinkwater et al., 2009; Wilson et al., 2013). This variability of the ecosystem and resources will be reflected in the fishing industry, causing the increasing variability that has been observed in landings (Halley & Stergiou, 2005). Among the factors affecting the variability are: predator-prey interactions, climate change, recruitment, patterns of distribution, seasonality and invasive species, among others (Bascompte et al., 2005; Pais, 2007; Badjeck, 2010; Teixeira et al., 2013). These factors could induce errors in the assessment of stock decline causes, thus leading to heavy management measures which will in turn affect the fishing industry and the whole economy that depends on it.

The sustainability of fisheries affects not only the ecosystem but also the population dependent on this industry, more specifically fishermen. The fishing sector is responsible for providing a significant amount of food for human consumption and simultaneously wage and employment to millions of people around the world, thus having an important role in the economy of many countries. As well as the capture of species, the fishing industry provides employment in ancillary activities such as processing, packaging, distribution, marketing, transformation, construction and equipment manufacturing, administration and research. In total, in 2010 fisheries (including aquaculture) have provided global livelihood to about 54.8 million people dependent on it, which represents 4.2% of the economically active population in agriculture in contrast to the 2.9% in 1990, while Asia led with about 87% of the world total. However, this difference is largely represented by the aquaculture sector. In fact the amount of people associated with capture fisheries declined from 87% in 1990 to 70% in 2010 and in most countries the employment rates in fishing stagnated or decrease. Europe has suffered the most with an average annual decline of 2% between 2000 and 2010 (FAO, 2012). Besides, according to a recent World Bank Report, it is estimated that the intensification of the global fishing effort and the consequent depletion of marine stocks annually causes economic losses of around 50 billion US dollars (The World Bank, 2009).

Fishing communities are largely affected by fisheries management measures. Parallel to this, they are the first to notice and identify the changes that occur in the marine ecosystem and in the stocks, since it directly affects their incomes and livelihoods (Friesinger & Bernatchez, 2010; Leite & Gasalla, 2013). Because of this, their way of life and livelihoods has been increasingly threatened, since they struggle to deal with the depletion of the stocks and with the increasing management measures (Allison & Ellis, 2001; Urquhart et al., 2013). Despite the existence of numerous studies on the human and fishing industry impacts in the marine environment, few studies are dedicated to approach the problem from the point of view of the fisherman and the consequences for him, with a limited knowledge about the social and economic impacts of this industry in their communities (Charles, 1988; Macfadyen & Corcoran, 2002; Hilborn et al., 2003; Badjeck, 2010; Carneiro, 2011; Coulthard et al., 2011). The social and cultural aspects of fisheries are less considered and poorly integrated into fisheries policy, focusing primarily on the biological component and economic impacts to a higher scale (Allison & Ellis, 2001; Hilborn et al., 2003; Urquhart et al., 2013). In 1990 about 28.5 million people depended on the fisheries sector and, in 2000, about 120 million people are involved in this industry (Allison & Ellis, 2001). However, only recently the stability of the fishing communities has becoming an objective to managers (Garcia et al., 2003; Brooks, 2010). One of the benefits derived from the perspective change of the management system, which includes the encouragement of public participation, is the fact that managers and decision-makers become more informed in what concerns to the fisherfolk (Allison & Ellis, 2001). Environmental sustainability in fisheries only can be achieved if the management integrates the economic and social factors related to fishing communities (Charles, 1994; Cinti, 2010). The first step in this process is to identify the most important impacts derived from the management of the fishing industry on coastal communities, and to collect rigorous socio-economic data on the conditions of these communities (Charles, 1988; Carneiro, 2011; Urquhart et al., 2013). It is therefore necessary to improve the knowledge of these impacts regarding the extent that the community is affected, which factors most contribute and what type of intervention is necessary to promote their protection and recovery (Charles, 1994; Cunningham, 1994; Garcia et al., 2003). The studies concerning this issue should be performed in a more analytical perspective, rather than focus in the descriptive way.

The aim of this study is to assess the variability of landings for different fleet components in the Portuguese mainland coast, in order to understand which of them showed more variability on landings and how it affects the fisheries. It was also to study the landings temporal trends and to conclude which species are most important in each region. The importance of this work is to allow the understanding of the national fisheries dynamics and the action of its factors. This information can be applied to the management measures and act like basis for possible forecasting models of Portuguese fisheries and the state of the stocks.

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# *Chapter 2*

Fisheries landings variability for different fleet components along the Portuguese coast
Fisheries Research (*submitted*)
By Amoroso, S., Gamito, R., Teixeira, C.M., Cabral, H.N.

# Fisheries landings variability for different fleet components along the Portuguese coast


## Abstract

Fisheries have a great associated variability, which directly affects the values of landings and the profits of fishermen. Portugal is traditionally and culturally linked to the fisheries sector and a significant part of the population is professionally dependent on this industry. Official data on landings and market price of the Portuguese fleet in the period of 1992-2012 were analyzed. In general, landings per unit effort and market price per kg showed an increasing trend. European pilchard, horse mackerel and octopus were the most exploited species through the whole time series with, for example, landing values that achieve about 22 million kg.year$^{-1}$ in what regards to the European pilchard. Norway lobster was the most expensive species, with average values of 16.22 €.kg$^{-1}$. The variability in landings was analyzed, and the purse seine fishery showed the highest variability, with average LPUE values varying up to 163 210.09 kg.vessel$^{-1}$ in the whole time series. Fisheries management must take into account these factors, particularly the variability, and further studies on the causes and consequences of the observed present results should be carried out.


**Keywords:** fisheries; landings; market price; variability; fleet component; Portugal

# 1. Introduction

Fisheries are an important resource for the world population, providing a great variety of products, food and jobs. These products are highly traded worldwide (Badjeck et al., 2010; FAO, 2012), therefore, it is an industry with a high socio-economic relevance, and a very competitive business (Bostford et al., 1997; The World Bank, 2009; Watson & Pauly, 2013).

In the last decades there has been a worldwide increasing pressure on the marine ecosystem and its resources (Bostford et al., 1997; Pauly et al., 2002; Baeta & Cabral, 2005; Zeller & Pauly, 2005; Costello et al., 2008), resulting in a significant decrease of catches, changes in the trophic level of harvested species and an increase of overexploited stocks (Pauly et al., 1998; Pauly et al., 2002; Pauly et al., 2005; Keyl & Wolff, 2008; Pauly, 2009; FAO, 2012). For these reasons, fisheries are currently considered an industry in crisis (McGoodwin, 1990; Pauly, 2009).

At the same time, the fishing industry continuously develops and modernizes its technology (Baeta & Cabral, 2005; Coulthard et al., 2011; Watson & Pauly, 2013) in order to be able to fish further, deeper and more precisely (Watson & Morato, 2013). It is estimated that each year the global fleet enhances its efficiency by 4% to 5% (Pauly, 2009) and that in the last three decades the number of fishermen has increased at a higher rate than the world´s population (Coulthard et al., 2011).

The marine ecosystem is very dynamic and with an inherent variability (Drinkwater et al., 2009; Perry et al., 2010). Despite the overexploitation of the stocks being the most often attributed reason to its impacts and observed changes, the variability of marine ecosystem is affected by a wide variety of factors, ranging from a seasonal scale to hundreds of years and longer (Spencer & Collie, 1997; Ravier & Fromentin, 2001; Erzini, 2005; Halley & Stergiou, 2005; Lehodey et al., 2006; Wilson et al., 2013). Among these are: recruitment, migration, trophic interactions, invasive species, patterns of abundance and distribution, environmental accidents, seasonality, climate change and another anthropogenic pressures and environmental changes (Spencer & Collie, 1997; Horwood et al., 2000; Lloret et al., 2001; Pais, 2007; Badjeck et al., 2010; Perry et al., 2010; Teixeira et al., 2013). The ecological relevance is that these variables affect the physiology and behavior of biological organisms, as well as the population's structure, and influence the composition and capacity of the ecosystem and consequently the efficiency and variability in the fisheries sector and abundance of stocks (Pauly & Christensen, 1995; Hofmann & Powell, 1998; Lehodey et al., 2006; Teixeira et al., 2013). While some of these events are well known among the scientific and fishermen communities (e.g. migration, seasonality), others are unpredictable or little is known about them. It is also often difficult to understand if the observed changes are due to the overexploitation of stocks or to natural events in the biological communities (Hofmann & Powell, 1998; Lehodey et al., 2006). Because if this, fisheries also have a great associated variability, with the previous referred environmental and anthropogenic sources that affects directly or indirectly the ecosystem and the dependent communities. These factors of variability are an additional pressure for the resources and for the fishermen, influencing the values of landings and, consequently, the socio-economy of the fishing community. Since the fisheries sector depends on the knowledge of the fishermen and scientists and on the predictability of resources, ecosystem and environmental patterns, the variability caused by the referred factors may undermine the fishing community. In other words, fisheries may become economically unsustainable because it will require greater investment and fishing effort to meet the population needs and the income to fishermen. The social relevance of this it that could also result in increased sales price due to that largest investment made, making more difficult to the population to achieve the fisheries products, mainly the ones with greater quality, which in turn will decrease the fishermen´s income. Furthermore, if fishermen feel the need to continue the modernization and potentiality of vessels to achieve exploited resources, stocks become increasingly overexploited. At the end, this situation ends up becoming a cycle of depletion of stocks and constant increase in fishing effort and selling prices.

Considering that the overall variability of fisheries has been increasing (Halley & Stergiou, 2005) it becomes important to implement more effective measures for fisheries management covering a wider variety of factors and to take into account the variability and ecosystem dynamics, as well as impacts bearing upon it (Hofmann & Powell, 1998; Worm et al., 2006; Gourguet et al., 2013; Teixeira et al., 2013; Watson & Pauly, 2013). It is also very important to consider the socio-economic factors and the quality of life and wellbeing of the fishing community. Fishing community's livelihoods has been threatened by the depletion of the resources and the management measures (Friesinger & Bernatchez, 2001; Urquhart et al., 2013). If we add to this the variability factor, they become increasingly vulnerable because of the unpredictability of the variability patterns, derived by the poor knowledge about it (Charles, 1988; Macfadyen & Corcoran, 2002; Hilborn et al., 2003; Badjeck, 2010; Carneiro, 2011; Coulthard et al., 2011). The ultimate goal will be to achieve a global ecologically and economically sustainable fishing industry.

In Portugal, the fishing industry is an important cultural and traditional activity, with a very diversified fleet (Baeta et al., 2009) dominated by multigear fishing vessels. The Portuguese fleet is currently composed of 8276 active vessels, of which 7051 comprise the mainland fleet (DGRM, 2013a). The average age of the vessels in mainland Portugal is 26.5 years (DGRM, 2013b). It is essentially divided in three major fleet components: trawl, purse seine and multigear. In the Portuguese coast a large number of important commercial species occur (Baeta et al., 2009; Teixeira et al., 2013), and Portugal is the third biggest *per capita* consumer of fish worldwide (Failler, 2007) and the greatest consumer at European level (Baeta & Cabral, 2005).

Considering the few studies about Portuguese fisheries which have long time series and are multi-specific (Erzini, 2005) and the absence of studies on fisheries variability and which take into account all the national territory, it becomes important to understand the variability at the temporal and spatial scale, to provide a basis for implementation of management measures that include this factor and that focus not only on the environment but also in the fishing community living conditions.

The aims of this study are to assess the variability of landings for different fleet components in the Portuguese mainland coast, in order to understand which of them showed more variability on landings and how it affects the fisheries. It was also to study the landings temporal trends and to conclude which species are most important in each region and provide more stability to fishermen. The importance of this work lies in the fact that we need more rigorous knowledge about the fishing industry in our country, evaluating its sustainability not only at the environmental level but also at the socio-economic level. Furthermore, there are no studies about the variability of Portuguese fisheries, and also they are few at the worldwide scale. The present study allows for the understanding of the national fisheries dynamics and the action of its factors. This information can be applied to management measures and provide a starting point for future forecasting models of Portuguese fisheries and stock assessments.

# 2. Materials and Methods

## 2.1 Data Source

The commercial data of fisheries analyzed in this work were obtained from the Governmental Fisheries Bureau (DGRM) spanning over a period of 21 years, from 1992 to 2012. This information contains annual data on landings and composition of the Portuguese fleet. All landings data were ordered by captured species and included the vessel number, year, landing port, fishing gear, species name, number of trips, weight and market price. The fleet data were composed per vessel number, age, gross tonnage, engine power, length, hull material and crew.

For the present study, three sectors of the Portuguese coast were considered (Figure 1): "North" from Viana do Castelo (41° 41´N, 8° 50´W) to Nazaré (39° 36´N, 9° 4´W); "Southwest" from Nazaré (39° 36´N, 9° 4´W) to Sagres (36° 59´N, 8° 56´W); and "South" from Sagres (36° 59´N, 8° 56´W) to Vila Real de Santo António (37° 11´N, 7° 25´W). This division of the Portuguese coast was based on oceanographic conditions and ecologic communities (Cunha, 2001; Sousa et al., 2005).

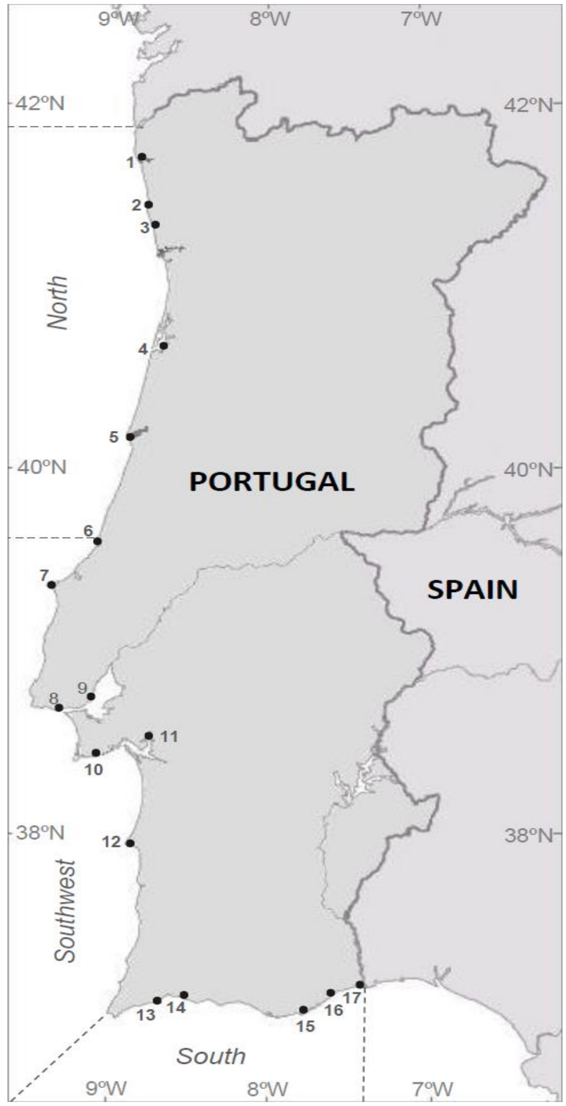



Figure 1. Map of mainland Portugal with the location of the main delegations landing ports and the sectors of division North, Southwest and South (1 – Viana do Castelo, 2 – Póvoa de Varzim, 3 – Matosinhos, 4 – Aveiro, 5 – Figueira da Foz, 6 – Nazaré, 7 – Peniche, 8 – Cascais, 9 – Lisboa, 10 – Sesimbra, 11 – Setúbal, 12 – Sines, 13 – Lagos, 14 – Portimão, 15 – Olhão, 16 – Tavira, 17 – Vila Real de Santo António).

### 2.2 Data Analysis

From the initial data, only vessels with at least ten years of landings in the whole series and using only one fleet component – either trawl, purse seine or multigear – were chosen. This choice was made in order to obtain the longest temporal series possible, eliminate the vessels with occasional landings and to allow a specific analysis for each fishing component. The analyzed data comprise 3809 vessels: 101 trawler, 55 purse seiner and 3653 of the multigear fleet. Species were grouped in order to identify the most important for each coast sector/fishing gear, in both landed weight and economic value for the fishermen. To evaluate how landings evolved over time, trend analyses were performed on the landed weight and market price, to compare spatially and temporally each fishing gear. The landing per unit effort (LPUE) was calculated by summing the total annual landings for every vessel and dividing it by the number of fishing trips and vessels per year. For each fishing component in each coastal sector, the species with the highest total weight landed and the highest total market price were selected as the dominant species.  The average total landed weight of each vessel in the whole series was used, in order to compare the variability of the spatial component in each fishing gear (intra-fleet component). To perform the inter-fleet component analysis, which aimed to compare the variability between each fishing gear, the average total landed weight of twenty randomly selected vessels for each coast sector/fishing gear was compared. A bootstrap analysis was first carried out. Random samples of 20 vessels for each coast sector/fishing gear, with average and standard deviation landing values were generated. Finally, 1000 bootstrap cycles were performed and the metric´s mean and standard deviation were obtained for each sample. For the coast sectors with a total number of vessels of 20 or less the random repeat of the vessels was allowed. This analysis was performed on the environment R version 2.13.1 (R Development Core Team, 2011) and aimed to provide an analysis of confidence to our inter-fleet component study, as the number of vessels varied among fleet components.

# 3. Results

## 3.1 Trends in annual landings

Most of the fleet components presented the lowest LPUE values around 2000-2003, except for the purse seine fisheries in the North sector. Following this period, there has been a recovery and a raising trend in all sectors and fleet (Figure 2). Considering the entire series, only the multigear fishing in North and the multigear fishing in South exhibited a decreasing general trend in LPUE values. The remaining ones clearly had an increasing general trend. Particularly, in the South sector of the purse seine fishing it was observed a high increase in these values. Regarding the market price values, there is a large variation over the years, but in almost all analysis with markedly increasing trends, except for the trawl fishing in Southwest with a steady tendency. In addition, in the South of trawl fishing and of purse seine fishing there has been a steep fall in market price values after 2000, followed by a recovery after 2005 and 2010.

The values of LPUE are very different among the three fleet components. The purse seine fishing is the component with higher LPUE, and the multigear fishing was the one with lower values, and the difference is from hundreds of kg to tenths of kg. In what concern for the market price we can verify a marked difference, with higher values in the multigear fisheries and lower in the purse seine fisheries. Regarding the trawl fishing, Southwest is where there are higher values of LPUE. South is where the values of LPUE are lower but market price is higher than in the other sectors. It is in the North that the market price is lower, although it is possible to observe a significant increase since the year 2006 which brings it to the actuality with the same set of values of the Southwest sector. As to the purse seine fishing, it is clearly in the Southern sector that is observed the highest values of LPUE. Yet, this only occurs since the year 2008. Prior this period landings were much lower. The lowest LPUE occurs in the Southwest sector, despite showing a noticeable increase since the year 2007.

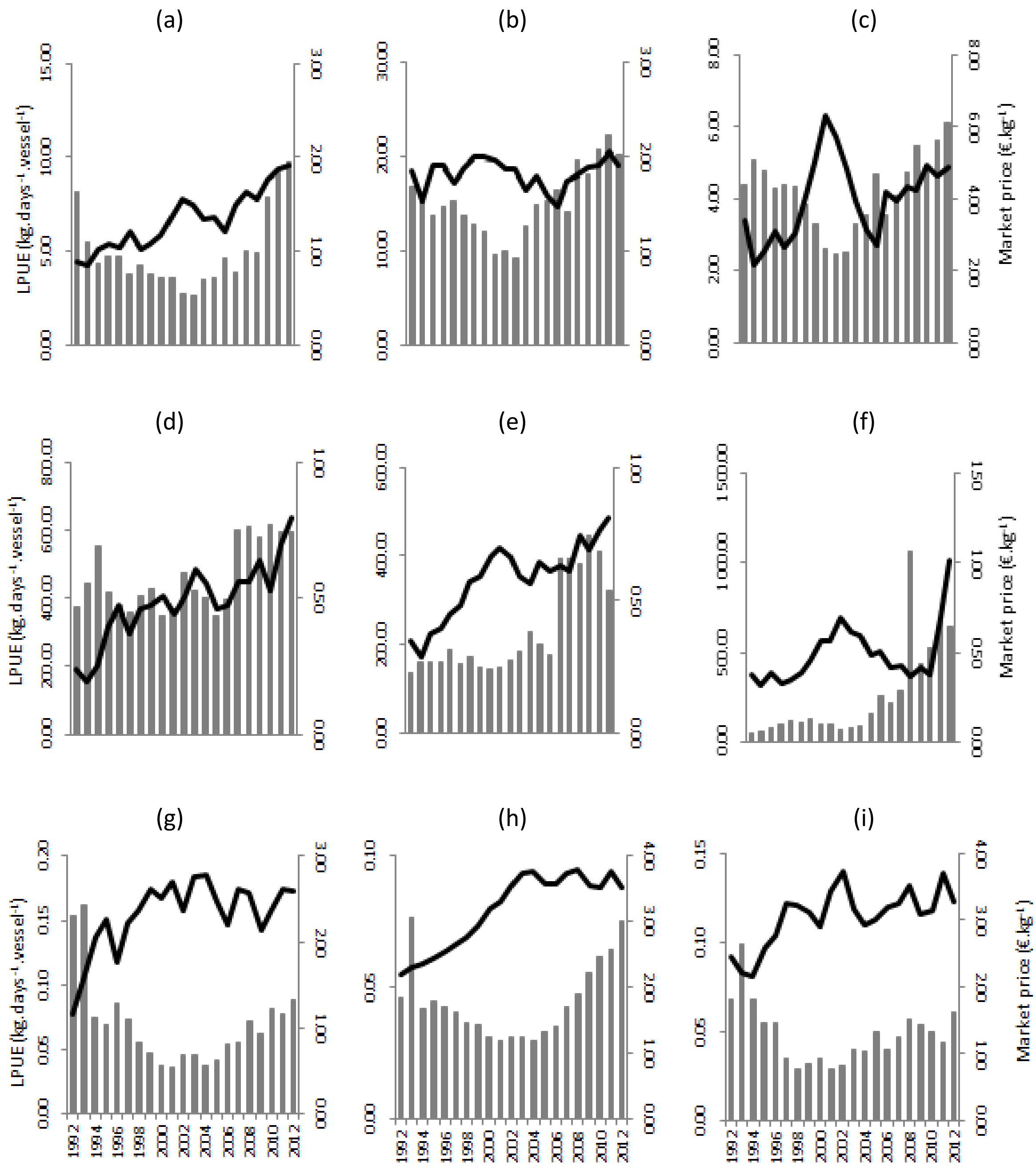



Fig. 2. Trends in annual values of LPUE (represented by bars) and market price (represented by line) for (a) trawl North, (b) trawl Southwest, (c) trawl South, (d) purse seine North, (e) purse seine Southwest, (f) purse seine South, (g) multigear North, (h) multigear Southwest and (i) multigear South (from 1992 to 2012).

As regard to the market price of the purse seine fishing, it is substantially similar in all sectors, but with a distinct increase in the South sector since the year 2010. Finally, in multigear fishing the highest values of LPUE are observed in the North sector and the ones of market price in the South. The lower values of market price occur in North.

In trawl fisheries, the horse mackerel (*Trachurus trachurus* (Linnaeus, 1758), *Trachurus mediterraneus* (Steindachner, 1868) and *Trachurus picturatus* (Bowdich, 1825)) was the most landed species for all sectors and in purse seine fisheries it is the European pilchard (*Sardina pilchardus* (Walbaum, 1792)). Regarding the multigear fisheries it is observed that the octopus (*Octopus vulgaris* (Cuvier, 1797) and *Eledone cirrhosa* (Lamarck, 1798)) was the most landed resource in North and South, and scabbardfish (*Lepidopus caudatus* (Euphrasen, 1788) and *Aphanopus carbo* (Lowe, 1839)) in Southwest. At national level, European pilchard, horse mackerel and octopus are the most landed species. European pilchard leads the national landings, with about 22 million kg landed per year. However, in relation to price per weight unit the main species are Norway lobster (*Nephrops norvegicus* (Linnaeus, 1758)), shrimps (*Melicertus kerathurus* (Forskål, 1775), *Crangon crangon* (Linnaeus, 1758), *Aristeus antennatus* (Risso, 1816) and *Plesionika* spp.) and soles (*Solea lascaris* (Risso, 1810), *Solea senegalensis* (Kaup, 1858) and *Solea solea* (Linnaeus, 1758)). The Norway lobster was the most expensive species, with average market price values of about 16 €.$kg^{-1}$ (Table 1).

Figure 3 shows the trends of the species that were considered to possibly reflect more economic stability and confidence for fishermen or more potential for fisheries. In trawl fisheries, the horse mackerel was the most important species in the entire coast. Despite suffering some instability, always has a high value of LPUE and in the last years shows an increasing trend. In purse seine fisheries also only one species was chosen for the entire coast. The European pilchard has shown an increasing trend and is the species with more stability in terms of values. The market price has increased significantly, making the European pilchard clearly the resource with more potential of income for fishermen in purse seine fisheries. As for multigear fisheries, species vary according to the coast sector. In the North the resource representative of greater confidence for fishermen was pouting (*Trisopterus luscus* (Linnaeus, 1758) and *Trisopterus minutus* (Linnaeus, 1758)). Despite having suffered a decline in values of LPUE since 1993, roughly from 1995 it remains fairly stable, and then increased from 2006 to nowadays. Although showing a decreasing trend in market price, is the species with highest LPUE values. In the Southwest it was the scabbardfish which clearly reflects a more stable trend in LPUE values. Regarding its market price the trend is steadily growing, being a resource of very high value. Finally, in the South the chub mackerel (*Scomber colias* (Gmelin, 1789)) does not exactly demonstrated stability but potential for fisheries towards being a resource with values of LPUE increasingly higher and with a moderate increasing trend in market price.

Table 1. Main species landed by the Portuguese fleet for each gear and sector of the coast between 1992 and 2012.

| *Coast Zone* | *Gear* | *Group* | *Number of species* | *Landing ($kg.year^{-1}$)* | *Value (€.$year^{-1}$)* | *Market price (€.$kg^{-1}$)* |
|---|---|---|---|---|---|---|
| **North** | *Trawl* | Horse mackerel | 2 | 6 806 834.852 | 5 521 706.94 | 0.81 |
| | | Blue whiting | 1 | 1 486 007.738 | 661 144.68 | 0.44 |
| | | Atlantic mackerel | 1 | 739 749.105 | 346 062.72 | 0.47 |
| | | Pouting | 2 | 556 377.176 | 870 401.36 | 1.56 |
| | | European pilchard | 1 | 490 047.340 | 152 747.20 | 0.31 |
| | | Hake | 1 | 209 838.624 | 771 549.25 | 3.68 |
| | | Others | 1 | 0.571 | 2.86 | 5.00 |
| | *Purse seine* | European pilchard | 1 | 9 052 038.524 | 3 933 770.10 | 0.43 |
| | | Chub mackerel | 1 | 450 605.224 | 107 039.95 | 0.24 |
| | | European anchovy | 1 | 280 749.095 | 366 888.79 | 1.31 |
| | | Horse mackerel | 2 | 210 854.410 | 206 526.03 | 0.98 |
| | *Multigear* | Octopus | 2 | 822 260.171 | 3 023 403.44 | 3.68 |
| | | Pouting | 2 | 620 509.381 | 1 187 112.25 | 1.91 |
| | | Common edible cockle | 1 | 547 920.648 | 317 658.00 | 0.58 |
| | | Horse mackerel | 3 | 381 104.552 | 477 809.51 | 1.25 |
| | | Hake | 1 | 160 449.248 | 561 118.65 | 3.50 |
| | | Soles | 3 | 83 601.267 | 696 295.71 | 8.33 |
| | | Others | 1 | 0.629 | 2.18 | 3.47 |
| **Southwest** | *Trawl* | Horse mackerel | 2 | 890 182.448 | 1 009 270.23 | 1.13 |
| | | Hake | 1 | 134 688.595 | 481 428.78 | 3.57 |
| | | Blue whiting | 1 | 121 315.167 | 73 581.01 | 0.61 |
| | | Axillary seabream | 1 | 63 471.410 | 253 329.34 | 3.99 |
| | | Others | 1 | 3.524 | 0.85 | 0.25 |
| | *Purse seine* | European pilchard | 1 | 8 793 929.971 | 4 508 981.80 | 0.51 |
| | | Chub mackerel | 1 | 882 070.033 | 270 392.67 | 0.31 |
| | | Horse Mackerel | 3 | 480 725.529 | 430 398.35 | 0.90 |
| | *Multigear* | Scabbardfish | 2 | 2 301 986.114 | 5 320 356.08 | 2.31 |
| | | Octopus | 2 | 1 291 507.452 | 5 252 070.51 | 4.07 |
| | | Sharks | 22 | 904 490.924 | 1 586 111.36 | 1.75 |
| | | Soles | 3 | 173 304.138 | 1 829 122.66 | 10.55 |
| | | Hake | 1 | 346 214.240 | 1 557 393.65 | 4.50 |
| **South** | *Trawl* | Horse Mackerel | 2 | 1 145 669.257 | 1 240 539.01 | 1.08 |
| | | Shrimps | 4 | 496 781.423 | 5 892 544.80 | 11.86 |
| | | Blue whiting | 1 | 210 191.367 | 107 712.64 | 0.51 |
| | | Chub mackerel | 1 | 183 824.191 | 62 445.72 | 0.34 |
| | | Hake | 1 | 157 497.719 | 512 197.99 | 3.25 |
| | | Axillary seabream | 1 | 141 932.819 | 466 393.20 | 3.29 |
| | | Norway lobster | 1 | 116 568.667 | 1 891 060.60 | 16.22 |
| | | Others | 1 | 1 094.800 | 1 352.97 | 1.24 |
| | *Purse seine* | European pilchard | 1 | 4 454 680.724 | 1 957 762.57 | 0.44 |
| | | Chub mackerel | 1 | 776 750.662 | 152 322.06 | 0.20 |
| | | Horse mackerel | 2 | 152 541.676 | 207 749.75 | 1.36 |
| | | European anchovy | 1 | 60 913.967 | 84 590.36 | 1.39 |
| | | Others | 1 | 750.381 | 2 589.35 | 3.45 |
| | *Multigear* | Octopus | 2 | 1 446 294.533 | 5 662 694.87 | 3.92 |
| | | Carpet shell | 3 | 456 925.781 | 224 532.33 | 0.49 |
| | | Chub mackerel | 1 | 395 849.662 | 129 235.27 | 0.33 |
| | | Cuttlefish | 1 | 227 304.371 | 840 833.97 | 3.70 |
| | | Bastard sole | 1 | 190 964.491 | 745 759.23 | 9.05 |
| | | Hake | 1 | 82 432.419 | 734 560.10 | 3.85 |

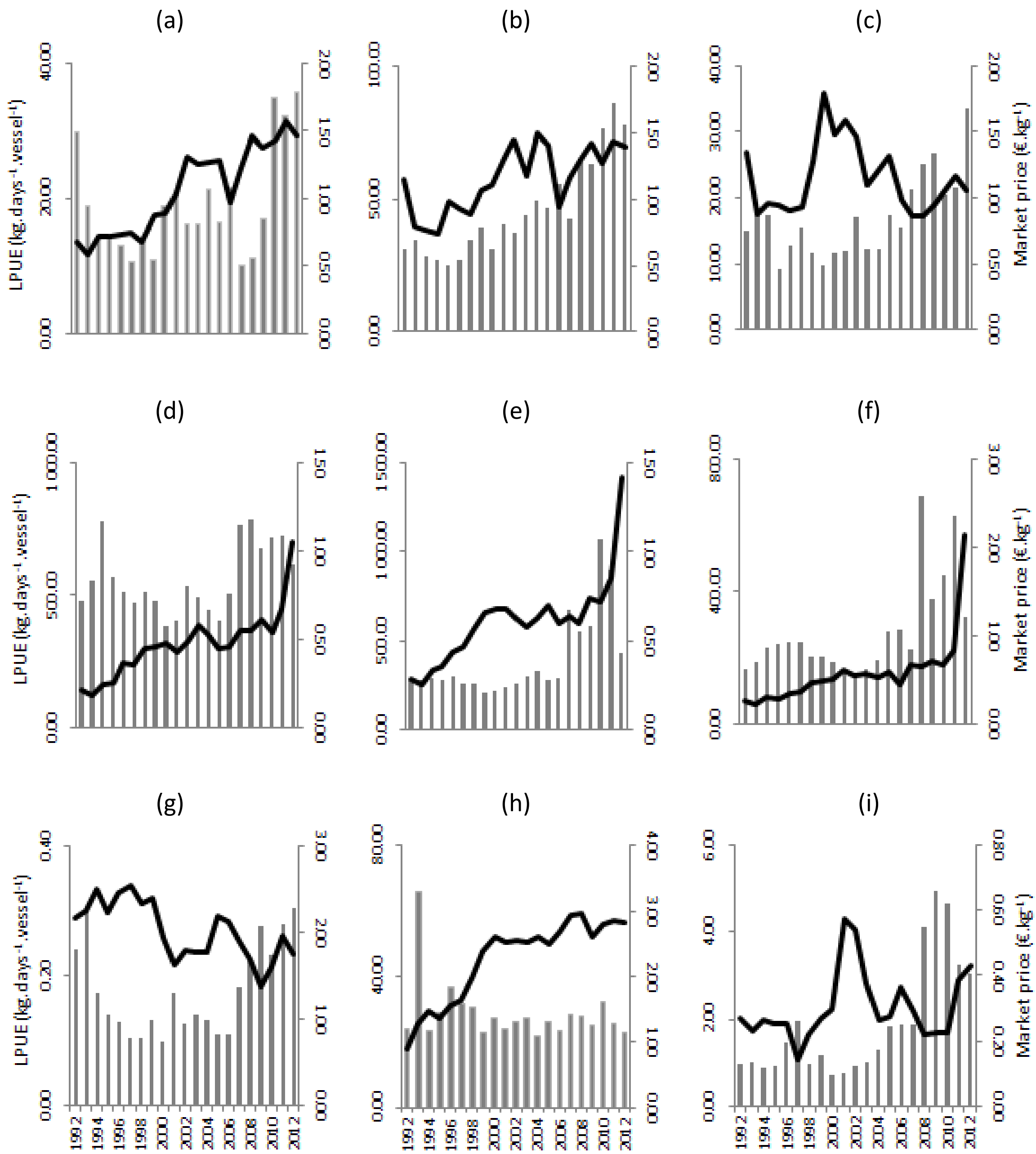


Figure 3. Trends in annual values of LPUE (represented by bars) and market price (represented by line) for (a) horse mackerel in trawl North, (b) horse mackerel in trawl Southwest, (c) horse mackerel in trawl South, (d) European pilchard in purse seine North, (e) European pilchard in purse seine Southwest, (f) European pilchard in purse seine South, (g) pouting in multigear North, (h) scabbardfish in multigear Southwest and (i) chub mackerel in multigear South (from 1992 to 2012)

### 3.2 Landings variability

Intra-fleet component analysis (Figure 4) was intended to compare the three sectors of the coast within each fishing gear.

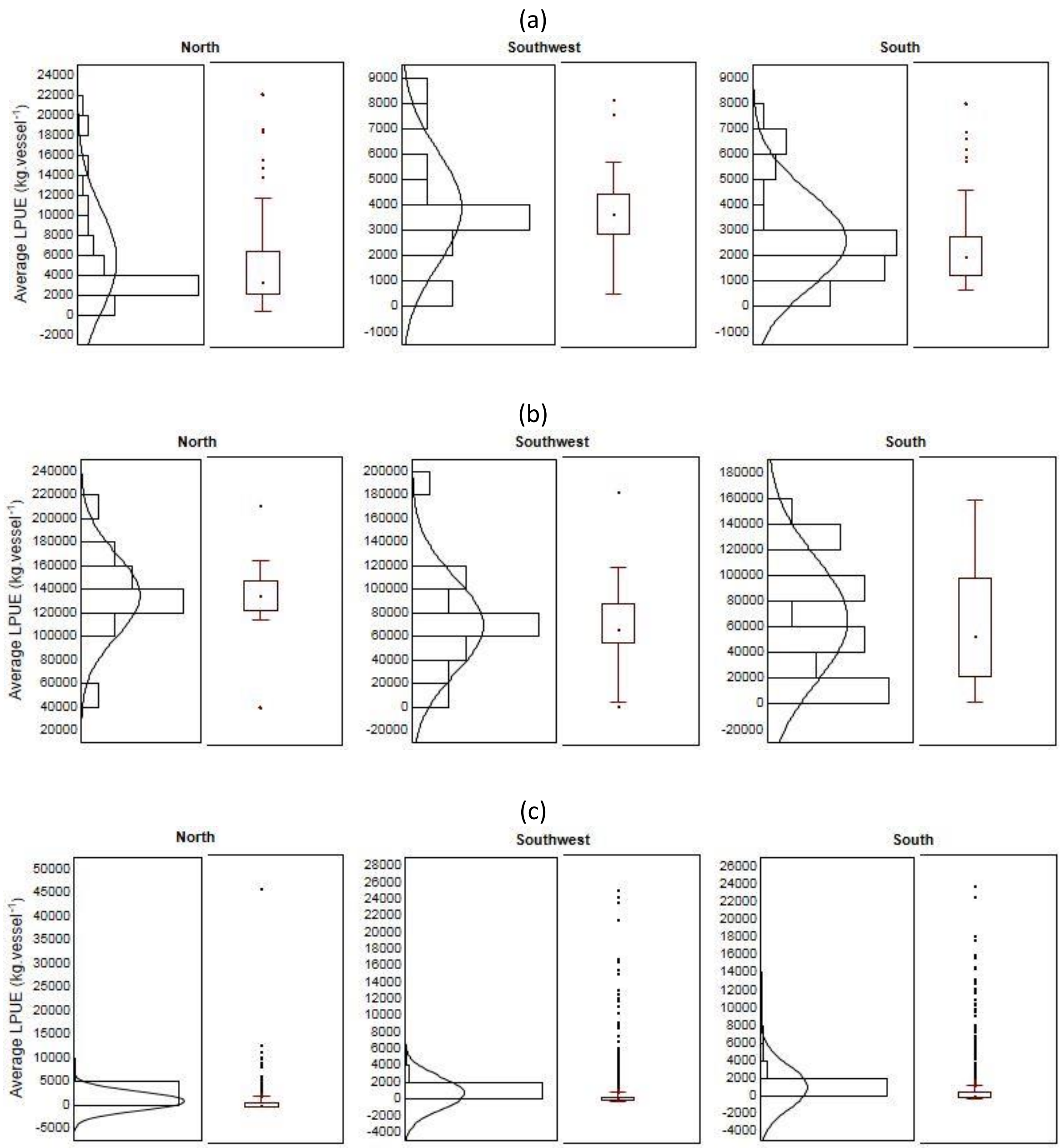


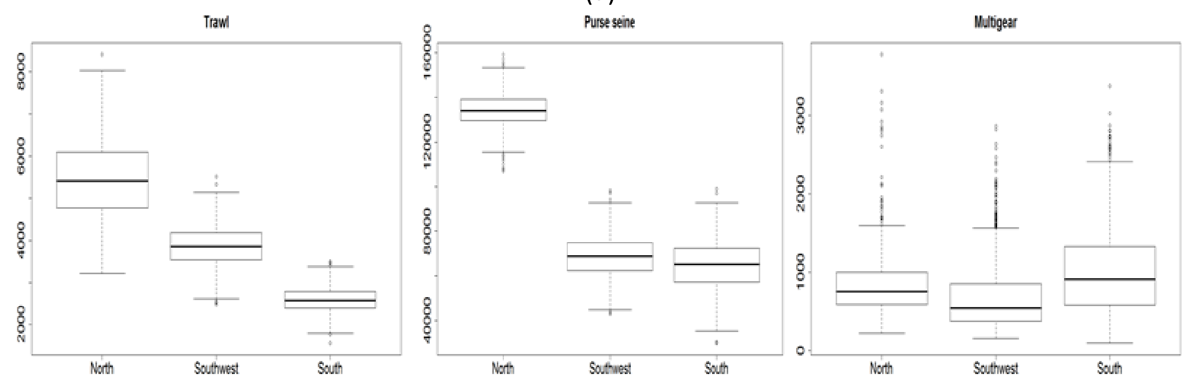

Figure 4. Intra-fleet component analysis for (a) trawl, (b) purse seine and (c) multigear (from 1992 to 2012).

Regarding the trawl fisheries, North has the highest variability and South is the sector with less variability, as they have respectively a greater and a smaller amplitude in values of average LPUE, with little more than twice the difference between the maximum values. As for purse seine fisheries, it is in the South that more variability in the average LPUE values is observed, and it is in the North that it is more limited.

Finally in multigear fisheries, despite the small variability that both sectors showed, it is in the North that this is more visible, being lower in Southwest. Nevertheless, this fishing gear presents for all the sectors a large amount of outliers in every sector, which means that landings with values much higher than usual sometimes occur.

However, if the the three components are considered together, in general was the North sector that showed more variability, with values ranging from 10.58 $kg.vessel^{-1}$ to 163 210.09 $kg.vessel^{-1}$.

(a)




(b)

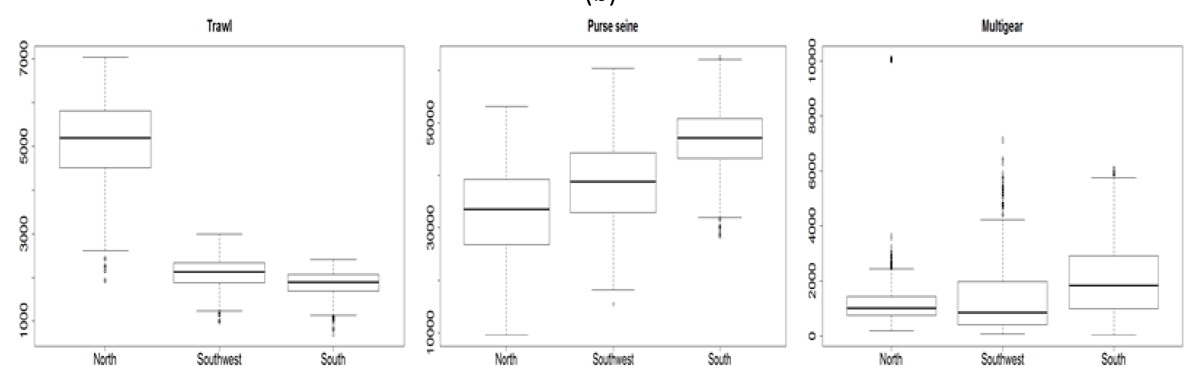



Figure 5. Bootstrap analysis with the metrics of (a) Average and (b) Standard deviation.

A bootstrap analysis were performed (Figure 5), which showed the representativeness of the sample chose for the inter-fleet component. For both the average and standard deviation it was verified a normal distribution of values, which gives confidence to the sample size. Through the inter-fleet component analysis (Figure 6) it was concluded that the purse seine fishing had a higher variability of landings in every sector, with a wider range of values of average LPUE. The average landing values of this fishing gear reaches the 163 210.09 kg.vessel$^{-1}$. Multigear was the fishing which showed lower variability of landings, ranging from 43.94 kg.vessel-1 to 1 822.90 kg.vessel$^{-1}$.

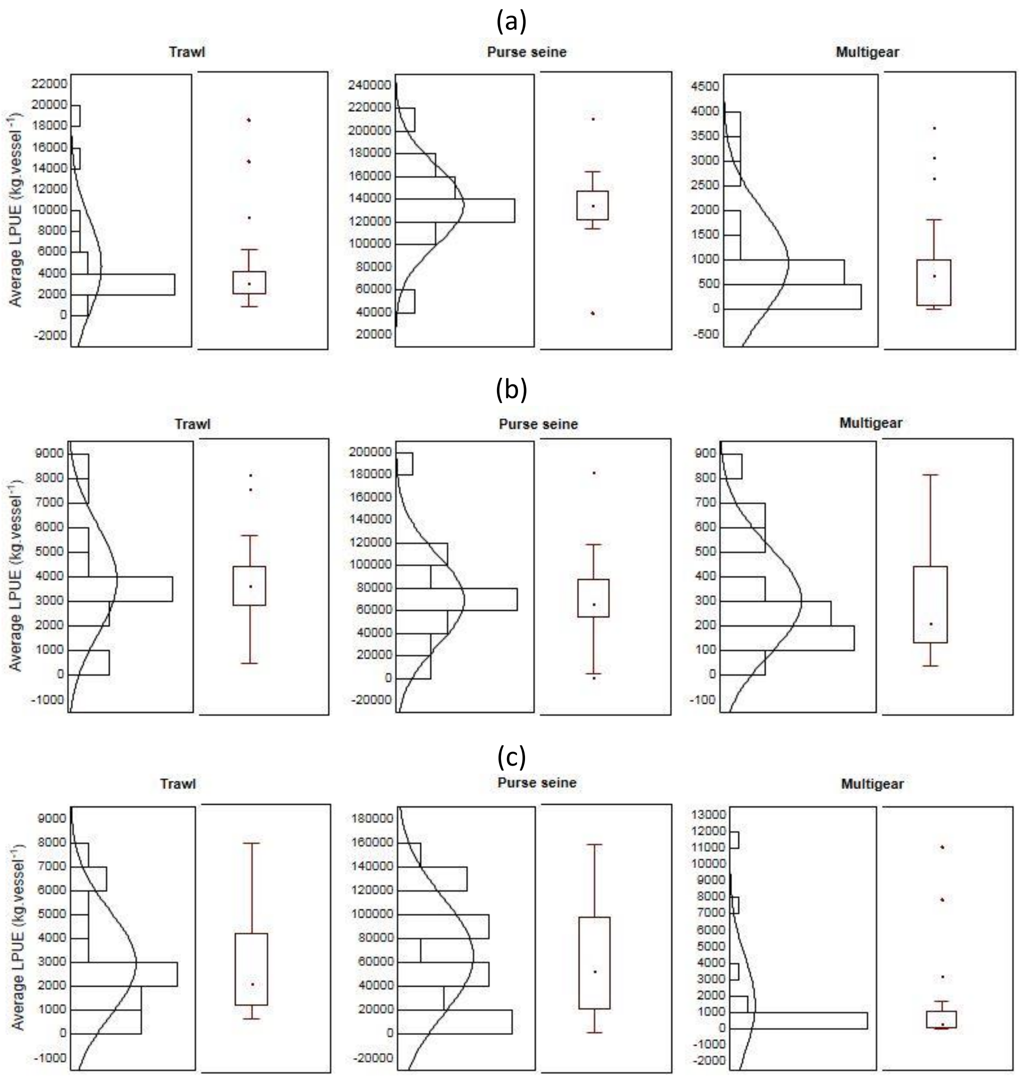



Figure 6. Inter-fleet component analysis for the sector (a) North, (b) Southwest and (c) South (from 1992 to 2012).

# 3. Discussion

In the present study we analysed the temporal and spatial trends on landings of fisheries in mainland Portugal. We have identified the most important species for this industry and studied the variability of landings.

The global values of LPUE and market price showed increasing trends. The majority of the studies on the landing trends use the gross total value of the landings, instead of the LPUE. Because of this, several studies, reports and communications have mentioned the occurrence of downward trends in national landings (Monteiro & Monteiro, 1997; Hill & Coelho, 2001; Erzini et al., 2007; Parente et al., 2007; Baeta, 2009; INE, 2013), reporting falls of about 9% in relation to 2011 (INE, 2013). In 2011 the landings of the multigear and of the purse seine fisheries falls about 10% and 7%, respectively. Regarding the trawl fisheries, it´s landings increased 4.3% in 2011. These general decreasing trends in national landings can be explained by the observed fall in the number of vessels in the Portuguese fleet (Monteiro & Monteiro, 1997; Valério, 2006; Parente et al., 2007; Baeta, 2009; INE, 2013). In fact, in 2012 there was a decrease of 1.3% in the number of vessels of the Portuguese fleet, comparing to 2011 (INE, 2013). Despite the fact that the landings per vessel are increasing, the strong decline of the fleet causes a downward trend in the global values of landings. Also the number of active people in the fishing industry has declined 18% between 2001 and 2011 (INE, 2013), and the fishing community is ageing, with an average age of 43.6 years in 2011 (INE, 2013), and has a low education level (Monteiro & Monteiro, 1997; Baeta & Cabral, 2005; INE, 2013). This situation shows a sector with little attractiveness to professional level. Nevertheless, Portugal is in 4$^{th}$ position in the European Union regarding the number of vessels, and in 6$^{th}$ position in relation to the capacity of the fleet (DGRM, 2013b). As a country closely linked to the fishing industry, with an important traditional and cultural component, it is important to understand the causes of this problem and to find solutions so that the fishing industry can continue to prosper in a sustainable way for the environment and for fishermen.

It was verified that market price shows a relatively marked increase in recent years. In fact, since 2011 the increase was of about 8% (INE, 2013). This may be due to greater fishing effort observed by fishermen to be able to exploit the resources, which includes modernization and improvement of vessels (Hill & Coelho, 2001; Valério, 2006; Villasante & Sumaila, 2010). Furthermore, the fact that exploited resources are suffering breaks in abundance (Comissão Europeia, 2009; FAO, 2012; INE, 2013) implies exploring new fishing grounds, spending more time and fuel and traveling longer distances to catch the exploited species in profitable quantities. It should be also considered that fish prices depend largely on consumer preferences and demand. Therefore, the fact that people increasingly search for this type of feed (Baeta & Cabral, 2005; Keyl & Wolff, 2008; Swartz et al., 2010) may also influence the observed tendency. However, it should be assessed the specific causes of this market price increase and search solutions to this values do not increase much more. This is because, although it is important to fishermen obtain profit, it is also important to the economic capacity of the population to access to quality food, especially in the present economic crisis (Tveterås et al., 2012).

By main species caught by each gear, can be clearly seen the characteristics of the Portuguese fleet. The purse seine fishing, being essentially a fleet component focused on shoals, has as main species small pelagics. In what concerns to the trawl fisheries, it is the semi-pelagic catches that dominate. The variety of strategies and gears of multigear fishing are demonstrated by the variety of resources that dominate landings from this component. The present work also demonstrated the importance of European pilchard, horse mackerel and octopus for the Portuguese fishing industry. These were clearly throughout the entire time series the resources with greater landings, generating globally higher revenue. These results are consistent with relevant scientific publication (Hill & Coelho, 2001; Baeta & Cabral, 2005; Batista, 2007; Parente et al., 2007; Sousa,

2008) and also with the general knowledge about the Portuguese dietary habits. With regard to the Portuguese preferred species for food, European pilchard, horse mackerel and octopus are distinguished by high demand and the strong connection to the cultures and traditions of the country. However, for the price per weight unit dominance belongs to Norway lobster, shrimps and soles. Despite being species caught in much smaller quantities, they have a high economic value and are therefore profitable for fishermen, even in small amounts. Indeed, the large difference in the market price of trawl fishing in North in relation to the remaining sectors is mainly due to the exploitation of Norway lobster and shrimps. From the economic point of view this is important, since it was a way to bring profit to the fishermen without the need for a higher fishing effort.

The fact that the European pilchard and horse mackerel have resulted as the species of greater confidence and capability to fishermen in purse seine and trawl fisheries, respectively, it is also consistent with the characteristics of these gears, consumption and demand of the population, and scientific knowledge about these fleet components and resources (Baeta & Cabral, 2005; Parente et al., 2007). Both, European pilchard and horse mackerel are pelagic with great socio-economic and cultural importance to the industry and population in general (Borges et al., 2003; INE, 2013). Generally, fishing industry is so connected and dependent on these resources that natural fluctuations, especially of European pilchard, seriously affect the fisheries sector (Borges et al., 2003). Once more, the multigear fisheries variety is verified to have one species corresponding to each sector regarding the stability for fishermen. The results are consistent with reality, since both the chub mackerel and scabbardfish are increasingly representative in the Portuguese diet and therefore the greater demand offsets their exploitation. In particular, the chub mackerel was a species with low economic value and thus on which occurred rejection. However, in recent years it has become more present in the diet of the population, economically offsetting their capture. Moreover, in 2012 the chub mackerel landings increased about 19% (INE, 2013).

In the intra-fleet component analysis, sectors varied depending on the fishing gear, with North dominating in trawl and multigear fisheries. At purse seine fisheries the sector with more variability was the South. The inter-fleet component analysis showed that purse seine is the fleet component with greater landings variability. This means it is the one whose average values have a greater range, varying from 2 772.42 kg.vessel$^{-1}$ to 163 210.09 kg.vessel$^{-1}$ in the whole time series. Given that is a fishing gear mainly aimed at shoals, it is normal since the amplitude observed depends greatly on the size of the captured shoals. In addition, it is a gear mostly linked to European pilchard (Hill & Coelho, 2001; Stratoudakis & Marçalo, 2002; Baeta, 2009) that is a species with many natural fluctuations and overexploited (Mendes & Borges, 2006; INE, 2013). This causes that the landings of this resource, which represents the majority of purse seine fishing landings, aren´t always high (Stratoudakis & Marçalo, 2002; Mendes & Borges, 2006). The purse seine is the fleet component that most contributes for the national landings (Monteiro & Monteiro, 1997; Hill & Coelho, 2001; Parente et al., 2007) and for the total sales value (Parente et al., 2007). The multigear fishing, being a fleet component more artisanal and selective but with different components (Duarte et al., 2009), naturally captures a greater variety of species but in smaller quantities. In addition, it is a gear whose dominant species generally don´t organize into shoals (Monteiro & Monteiro, 1997). These factors are reflected in the low variability of the results for this fishing gear, with its average values varying from 43.94 kg.vessel$^{-1}$ to 1 822 kg.vessel$^{-1}$ in the considered time series.

However, the variability of landings may be due to several environmental or anthropogenic factors. Not only fisheries affects the stocks but also other factors such as changes in natural patterns, climate change, recruitment, seasonality, among others (Pais, 2007; Badjeck et al., 2010; Gamito et al., 2013; Teixeira et al., 2013). Therefore, more research is necessary to assess the causes of this variability, so that this knowledge can be applied to fisheries management

The data used for this study was based on the values of national landings. The use of landings is not a rigorous evaluation of the abundance of stocks, since landings and catches are not synonymous. So, what we get is an underestimate analysis, so the ideal it would be to use the values of the catches, because then we would have to make sure of the all species captured and their values, including these who suffer rejection or that are sold before landing. However, landings data are very important because they also allow us to obtain an idea about the state of the stocks, the fisheries trends and the ecosystem dynamics to a large scale (Stergiou & Christou, 1996; Pauly et al., 1998; Erzini, 2005; Erzini et al., 2007; Teixeira et al., 2013).

The relevance of this study focuses on the junction of the socio-economic and the environmental factor, and the objective to realizing the variability of fishing gears and how it affects de population dependent on the fisheries sector. When there is more variability, unpredictability also an increase, which brings problems to fishermen whose work depends on the predictability of the resources patterns. This means that especially in relation to purse seine fishing, which according to this study is the fleet component with more variability in Portugal and also the largest contributor for landings (Stratoudakis & Marçalo, 2002), management measures should be more effective and take into account this factor. Currently, the method of management in Portugal is based in Total Allowable Catch (TAC), not taking into account the ecosystemic factor or the environmental and landings variability (Erzini et al., 2007; Comissão Europeia, 2009). This shows the need to apply these studies to the management practice.

It was also crucial the analysis that allows to conclude about the species that have more potential for confidence and stability for fishermen. This is important because as being those with more potential and more exploited, management plans should be developed that allow the continuity of their exploitation but also their protection so that stocks do not collapse. The dissemination and communication to the public towards the consumption of alternative species would be an essential step for the preservation of the most exploited. Since the exploitation of marine resources largely depends of associated demand, this would lead fishermen to exploit more species not exerting much pressure on them.

Portuguese waters are subject to intense fishing pressure (Campos et al., 2007), so the existence of multi-species studies at national level and with long time series is quite important. These studies provide information about long-term evolution of the fishing industry; however they are scarce (Erzini, 2005; Erzini et al., 2007; Duarte et al., 2009). Both a national and global problem is associated with the lack of quality data on landings, since the species are often associated in general groups or bad identified (Watson & Pauly, 2001; Pauly et al., 2005). Also the studies about the fishing effort are few and these would be important to realize the extent to which fleet are overcapacitated (Villasante & Sumaila, 2010). Another important factor is the introduction of the socio-economic factor on the fisheries management. Environmental sustainability cannot be achieved without economical sustainability. Portuguese fisheries are not sustainable (Baeta, 2009) and a significant part of the population directly or indirectly depend on this industry, and as such it should be taken into account the socio-economic conditions of those individuals and include them in decision making process and management (Comissão Europeia, 2009; Wiber et al., 2009).

In conclusion, despite landings per vessel are increasing, global landings are decreasing, probably due to the cessation of fishing by professionals of the industry. The increasing prices may be due to the scarcity of the stocks and possibly to the greater fishing effort applied, and it is worrisome in a society with economic crisis. The most important species are under great exploitation pressure and alternatives to its consumption should be sought and disseminated, as well as to implement measures for their sustainable exploitation, keeping its importance. With regard to variability, this is very poorly known and extensive studies must be carried out to better understand the causes and consequences, since it depends on several factors.

Finally, to achieve sustainable fisheries and maintain the industry professionally attractive, Portugal must implement a management plan based on an ecosystemic, socio-economic and multifactorial vision. For management to be effective, the population must be enclosed using public and stakeholder's participation, and investing in communication to public and fishing community. Surveillance should also be improved, penalizing efficiently undue practices (Monteiro & Monteiro, 1997). With the potential of the Portuguese coast, if sustainable fisheries are reached, the socio-economic improvement will be relevant for a country traditionally closely linked to the sea.

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# *Chapter 3*

# Final Remarks

Fisheries management worldwide has been based on the concept of protecting the target species, without considering the surrounding environment, the multiple factors incidents on marine resources and the socio-economy dependent on this sector (Pais, 2007). In the European Union, subsidies to the fishing industry (Khan et al., 2006) and the lack of efficient inspection led to an excess fleet capacity, resulting in the decline of commercial fish populations (Comissão Europeia, 2009; Froese & Proelß, 2010; Sumaila et al., 2010; European Commission, 2011; ICES, 2011). It is essential to reverse this situation not only for the environment but also to recover the fishing industry and for the population that depends on it, since marine resources provides globally not only food but also employment and socio-economic benefits.

Portugal adopted the policy of the European Union since he joined this community in 1986, based on its management of the Common Fisheries Policy. This policy is essentially based on two types of measures to control resources exploitation: Total Allowable Catch (TAC) and technical regulations of vessels (Daw & Gray, 2005). It aims to reduce the overexploitation of stocks, limiting fishing effort by controlling the capacity of vessels and limiting the time spent at sea. This strategy is also the most applied worldwide. However it becomes increasingly clear the global crisis in the fishing industry and the critical state of the stocks (Watson & Pauly, 2001; FAO, 2012; INE, 2013). Currently, about 57% of the global stocks are fully exploited and 29.9% are overexploited (FAO, 2012). According to the current reform of the Common Fisheries Policy, the objectives of the previous policy had not been achieved (Comissão Europeia, 2009; European Commission, 2011) and the fishing industry is now in crisis, adjective avoided by the European Commission until the reform of the Common Fisheries Policy (European Commission, 2002; Rossiter & Stead, 2003). Not only the stocks are overexploited, as the economic situation of the fleet, industry and dependent communities is fragile and precarious (Rossiter & Stead, 2003; European Commission, 2011). According to the new

Common Fisheries Policy (Comissão Europeia, 2009; European Commission, 2011) a new vision must now be implemented directed towards ecosystem-based management and with sustainability as a central point of fisheries management.

The present study shows that the fishing effort in Portugal continues to increase as the values of LPUE have increasing trends, although it is known that the values of total national landings have decreased (Baeta, 2009; INE, 2013), as well as the professional attractiveness of this industry (INE, 2013). Similar studies should be performed to evaluate those trends at a more detailed scale, as it can be caused by several factors. The improvement of the classification systems of the landed species is also essential for studies with more precise information, as well as it will be ideal that we can get the value of the rejections and sales prior to landing.

Also market prices showed increasing trends along the time series. The commercial value of the species defines the investment that fishermen are willing to do to capture them (Pinnegar et al., 2006). Current knowledge suggests that prices are a reflection of the state of the stocks, in other words, the rarer a species is, the more expensive it becomes (Pinnegar et al., 2006). Market price is also a good indicator of species that are potential to become alternatives when target species are not available (Sumaila et al., 2010). Thus, this variable could be used to appeal to the exploration of alternative species, allowing the reduction of fishing pressure under the currently most exploited resources.

The United Nations established the year 2015 as the deadline for the establishment of measures to recover and maintain stocks in order to achieve the maximum sustainable yield (United Nations, 2002). However, the majority of stocks are far from reaching this level (Froese & Proelß, 2010). Put this together with the fact that the ecosystem is extremely dynamic and influenced by other factors besides the overexploitation (Drinkwater et al., 2009; Perry et al., 2010; Teixeira et al., 2013), it is expected that the state of stocks is not recoverable until the established limit since they become more vulnerable (Froese & Proelß, 2010). Perhaps the most worrying is the fact of being constantly established goals that are not likely to be met on time. The European Union undertakes to restore stocks at maximum sustainable yield by 2015 and eliminate discards by 2016 (European Commission, 2011). We´re presently in 2013 and no improvements are seen at this respect (Froese & Proelß, 2010).

This work was also demonstrated the variability between both fishing gears and among the different sectors in which we divided the Portuguese coast. The purse seine fishing stood as the fleet component with more variability due to its heavy dependence on European pilchard catch. This is worrying because when patterns fluctuate, European pilchard fishing is affected (Borges et al., 2003) as well as the profit of the fishermen. Alternative species should be sought in order to this gear does not depend so much on a single species and does not put so much exploitation pressure, since these stocks are overfished and threatened enough.

Once management measures should be taken based on the best available knowledge about the nature of the exploited resources (Daw & Gray, 2005), the difficulty in achieving the defined objectives and the sustainability of fisheries also stems from the lack of more knowledge. We know that stocks are overexploited and in decline, we know that the fleet situation is precarious and that landings are declining. Now the current studies should focus on the theme of this work. The variability is an important factor to take into account in fisheries management. It is necessary to understand how different factors affect the variability not only of the ecosystem but also of the landings, to realize how to prevent it from affecting the socio-economic development and the stability of the fishery resources. Moreover, this factor can mask the effect of other variables incidents on resources, making us assign overfishing as the cause of fluctuations or changes in patterns and abundance of resources (Pauly & Christensen, 1995; Alheit et al., 2005; Lehodey et al., 2006).

It is also important to carry out more studies on the quality of life of the community dependent on the fishing industry and the consequences caused by the applied management measures, as this sector has the potential to reduce poverty and the lack of food (Carneiro, 2011; Crilly & Esteban, 2013). If a good quality of life for the population dependent on fisheries can be achieved, management measures to protect the environment and the resources will be more easily accepted. Here enters the issue of stakeholder participation. From the fishermen point of view, their opinion has been ignored (European Commission, 2002; Rossiter & Stead, 2003). It should be given to fishermen the opportunity to express their opinion and to participate, as well as share their knowledge and experience. This would lead to the sharing of responsibility in fisheries management and to a better management of this industry (Berghöfer et al., 2008; Mikalsen & Jentoft, 2008).

The central question that remains is how to continue to maintain fisheries production and at the same time stop the overexploitation of resources and recover the declining stocks? There is no single perfect solution (Sutinen, 1999; Rossiter & Stead, 2003). Many aspects of fisheries and marine resources are still unknown and others are difficult to predict or control (Schrank, 2007). For this problem solutions should be sought that encompass the ecosystem dynamics and the associated factors, the socio-economy and public participation. The performance of forecasting models would be essential for stakeholders and decision-makers to anticipate results and decide the management measures needed for the sustainability of fisheries. Above all, it is necessary to achieve harmonization of measures and behavior of different countries, as resources knows no boundaries.

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